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**APPENDIX A**

**CAP ARMORING EVALUATION**

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## Memorandum

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**To:** John Verduin, P.E.

**From:** Greg Guannel

**CC:** Clay Patmont

**Date:** September 24, 2004

**Re:** Upriver Dam Cap Stable Sediment Size Determination

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Contaminated sediments have accumulated in a 3.7-acre area (denoted Deposit 1) within the old thalweg of the Spokane River, located immediately above the Upriver Dam in Spokane, Washington (Figure 1). One option that is being evaluated to remediate the Site, which has been a backwater area since the construction of the dam, is to cap these sediments with clean material that will remain stable during the strongest storm events. This memorandum presents the results of an analysis conducted to provide an initial Feasibility Study-level determination of cap armor material size.

Stable sediment size that could compose the erosion layer of a cap at the Site was determined based on maximum predicted velocities that can occur at the Site. These velocities were computed by dividing design flow value in the river by river cross-sectional area at the Site. Flow values have not been computed for river segments located above the dam. However, Avista (2004) conducted a flow analysis in the lower portion of the river and developed a 100-year flow value of 53,900 cubic feet per second (cfs). This value was used as the design flow value for our analysis.

Two representative river cross-sections were used to compute design velocity in the river (Figure 2). Cross-section A-A' is located within Deposit 1, and cross-section B-B' is located upstream end of the deposit, at the bend in the river. Design river average velocities at these two cross-sections are presented in Table 1.

**Table 1**  
**Design Velocities in Project Area**

<b>Section</b>	<b>Flow [cfs]</b>	<b>Area [sf]</b>	<b>Avg. Velocity [ft/s]</b>
A-A'	53,900	10,725	5.0
B-B'	53,900	6,079	8.9

Based on these velocities, stable sediment size was computed using the following methods:

1. Hjulstrom's diagram, as presented in Vanoni (1975)
2. Plate B-28, entitled "Noncohesive Sediment Gradation and Permissible Velocity," as presented in U.S. Army Corps of Engineers' (Corps) "Hydraulic Design of Flood Control Channel" (1994)
3. Plate B-29, entitled "Stone Stability: velocity vs stone diameter", as presented in the Corps's "Hydraulic Design of Flood Control Channel" (1994)
4. Shield's diagram, as presented in Shields (1936), based on bottom shear stress associated with channel average velocity. A Shield coefficient of 0.047 corresponding to gravel size material was used (Grindeland 2003). Bottom shear stress associated with design velocities was computed based on the following equation (WES 1998):

$$\tau = \frac{1}{2} \rho f_c U^2$$

Where:  $\tau$  represents the bottom shear stress

$\rho$  represents the density of freshwater

$f_c$  represents a friction coefficient

$U$  represents the average velocity in the river

The friction coefficient was approximated using the equation presented in WES' Technical Note (1998).

Stable sediment sizes at the Site were computed using the four different methods, for the two different cross-sections defined at the Site. Results are presented in Table 2.

**Table 2**  
**Stable Sediment Size that can Resist Design Flow Values at Section A-A' and B-B'**

Section	Velocity [ft/s]	Stable Sediment Size (inches)			
		Hjulstrom	Plate B-28	Plate B-29	Shields
A-A'	5.0	0.6	0.2	N/A	1.0
B-B'	8.9	2.4	5.1	6.6	3.4

Under all four methods, the median stable sediment size computed for the Deposit 1 area (Section A-A') is at or below 1 inch (Table 2). As expected based on the design velocities values, a somewhat larger stable sediment size may be needed in the vicinity of the Section B-B' cross-section. However, specification of a 1-inch median sediment size as the preliminary cap armor layer should provide for sufficient stability and resistance to erosion in Deposit 1 for the following reasons:

- Deposit 1 is located in a deeper portion of the Site, in a backwater area where fine sediments have accumulated.
- The bottom slope at the project area is very flat (approximately 1:170), and shear stress computed based on Site slope and hydraulic radius (Henderson 1966) led to a relatively small size in the required erosion protection layer, indicating that finer material is theoretically stable in this region.

Consequently, it is reasonable to assume that a preliminary specification for the cap erosion layer in Deposit 1 could consist of a material with a mean grain size of 1 inch, with a possible gradation specification of 100 percent passing 4 inch, 50 percent passing 1 inch and no more than 5 percent passing a number 200 sieve. As part of final design, a more detailed hydrodynamic analysis would likely be completed using a more refined modeling analysis (e.g., 2-D SEDZL or HEC-RAS), that could address the effects of river meander and dam configuration/operation characteristics on hydrodynamics and bottom shear stresses at the Site. The design-level hydrodynamic model would be used to refine conservative shear stress estimates developed above, and would likely conclude that a smaller armor grain size (i.e., less than 1-inch diameter) would suitably resist erosion potentially associated with peak flow events.

Gravel components of the standard AquaBlok™ formulation as well as the cohesive strength of the clay fraction should already be sufficient to resist the design erosive forces due to the presence of engrained gravels and the cohesive nature of the AquaBlok™ material. As generally described by the Hjulstrom diagram (Figure 3), both the gravel (nominal 20 mm materials) and bentonite/clay components (nominal 0.01 mm materials) included as part of standard AquaBlok™ formulations have the capacity to resist erosion during peak flood flows (velocities up to 5 feet/second). Again, more detailed hydrodynamic analyses would be performed during remedial design to develop final cap and armor specifications.

## REFERENCES

Avista, 2004. "SPOKANE RIVER HYDROELECTRIC PROJECT, FERC No. 2545." Application for New License Major Project—Existing Dam. VOLUME II, Part 1 of 2. Applicant-Prepared Preliminary Draft Environmental Assessment, 18 CFR, Part 4, Subpart F, Section 4.51. Prepared by Avista Corporation, Spokane, Washington, as a first working draft provided for Plenary Group review.

Grindeland, T. 2003. Personal conversation between Greg Guannel from Anchor Environmental and Tom Grindeland, P.E., from WEST Consultants.

Henderson, F.M. 1966. "Open Channel Flow." Macmillan Series in Civil Engineering. New-York. 522 pp.

Shields, A. 1936. "Anwendung der Aenlichkeitsmechanik und der Turbulenzforsschung auf die Geschiebebewegung." *Mitteilungen der Preussichen Versuchsanstalt fur Wasserbau und Schiffbau*. Berlin, Germany translated by W.P. Ott and J.C. van Uchelen, California Institute of Technology, Pasadena, California.

U.S. Army Corps of Engineers (USACE), 1994. "Hydraulic Design of Flood Control Channels", Engineer Manual No. 1110-2-1601 Change 1

U.S. Army Engineer Waterways Experiment Station (WES), 1998. "LTFATE cohesive sediment transport model." Technical Note DOER-N1. Vickburg, MS.

Vanoni, V.A. 1975. "Sedimentation Engineering." ASCE Manuals and Reports on Engineering Practice-No. 54. New York. 745 pp.